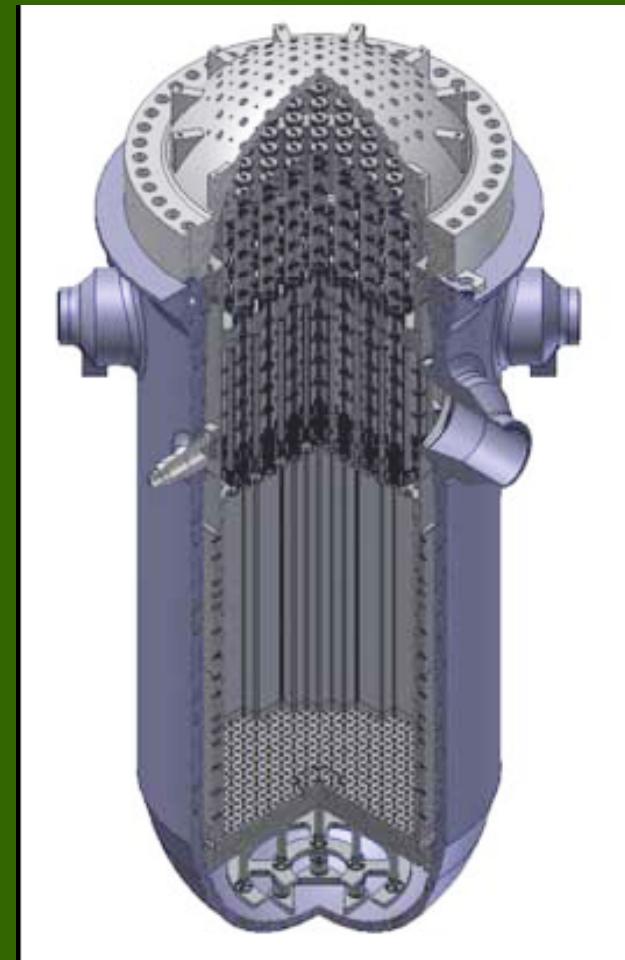




# Reactor Core & Vessel Design

AP1000 Technology  
Chapter 2.0

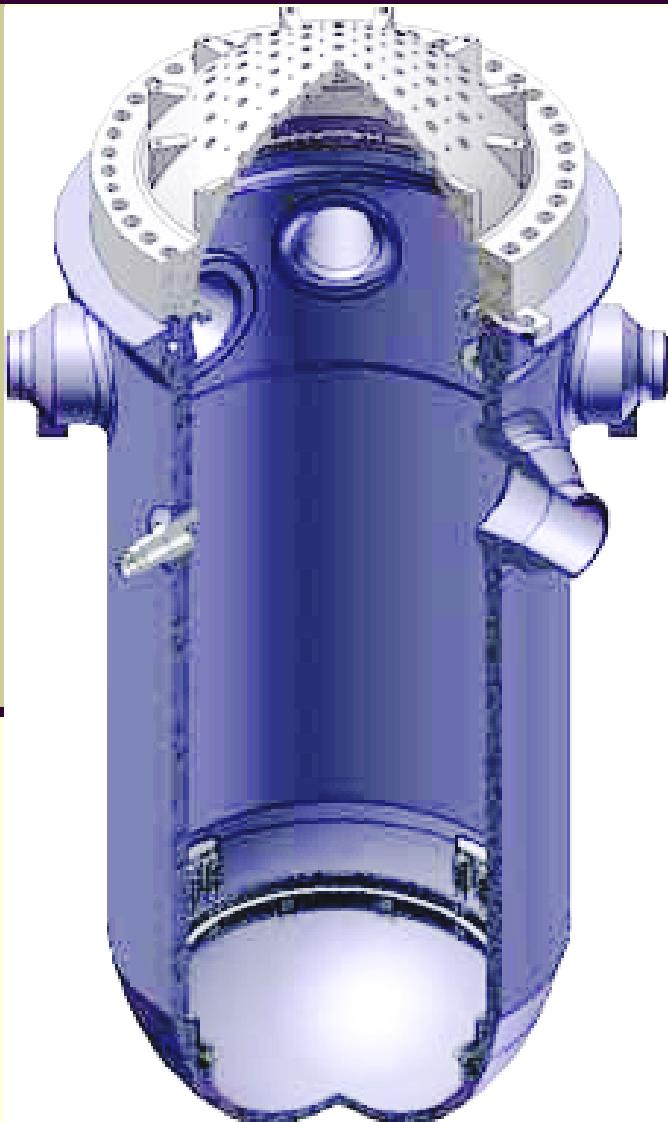


# Objectives

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1. Describe the basic differences in the construction of the AP1000 reactor vessel from a standard three loop reactor vessel.
2. Describe the basic construction of an AP1000 fuel assembly.
3. Explain the difference in the construction of a rod cluster control assembly and a gray rod cluster assembly.

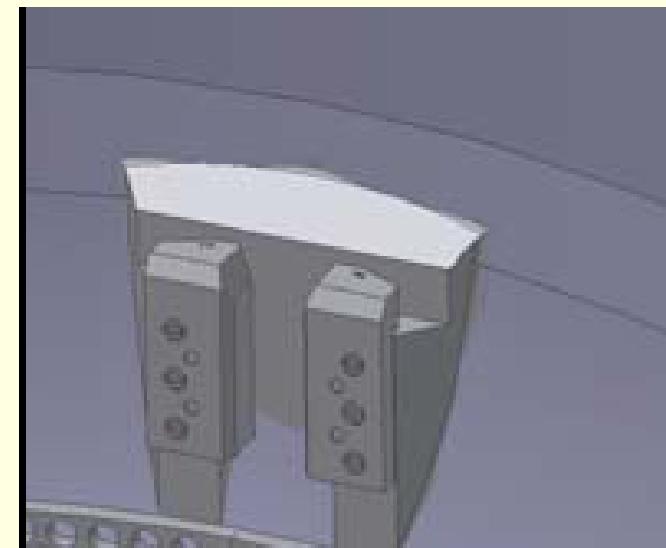
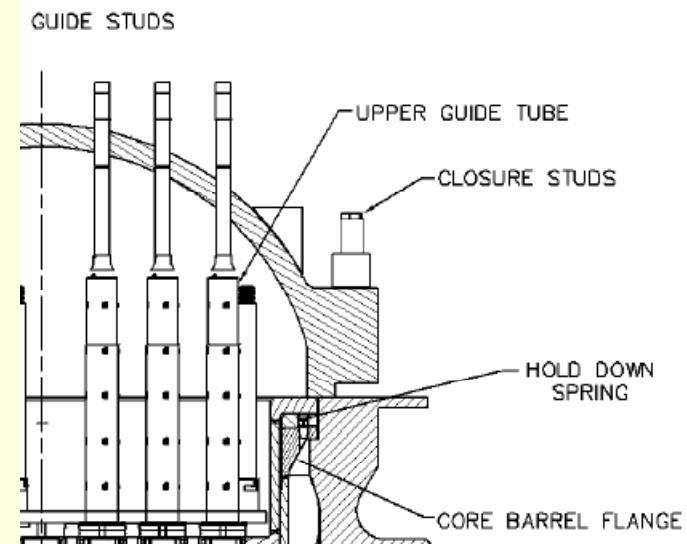
# Reactor Vessel



1. Reactor vessel is a modified three-loop Westinghouse reactor vessel.
  - because of two SGs with four RCP loop design,
  - direct vessel injection nozzles, and
  - 14 ft fuel assemblies.
2. ~40 feet long with an inner diameter of 159" in the core region.
3. Constructed of low alloy steel plates and forgings with a 0.22 inch SS internal clad.
4. There are no penetrations below the top of the core.
5. An integrated head package is used (more later)

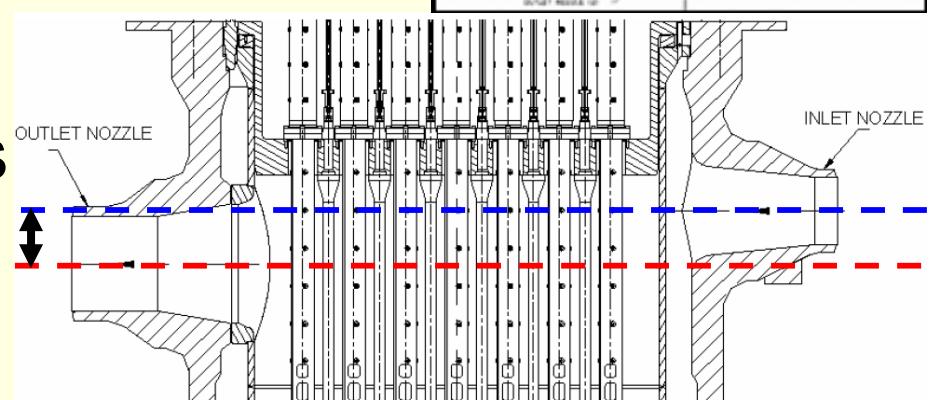
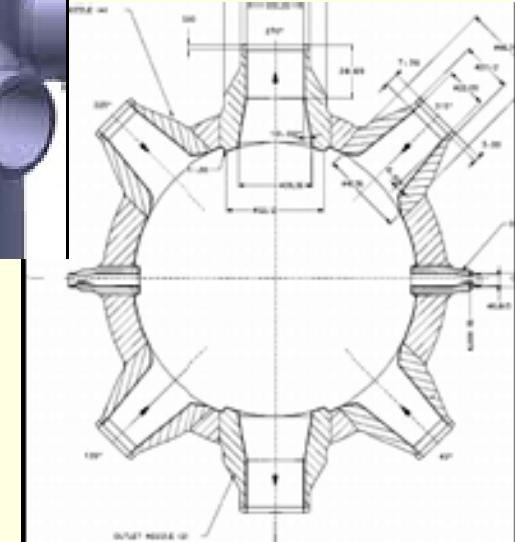
# Reactor Vessel Functions

- Support the RV internals and core
  - Internal ledge, core barrel flange
  - Four core support pads on vessel align with core barrel keys to provide lateral support
- Locates and aligns RV internals
  - Radial key/keyway joints



# Reactor Vessel Functions (cont.)

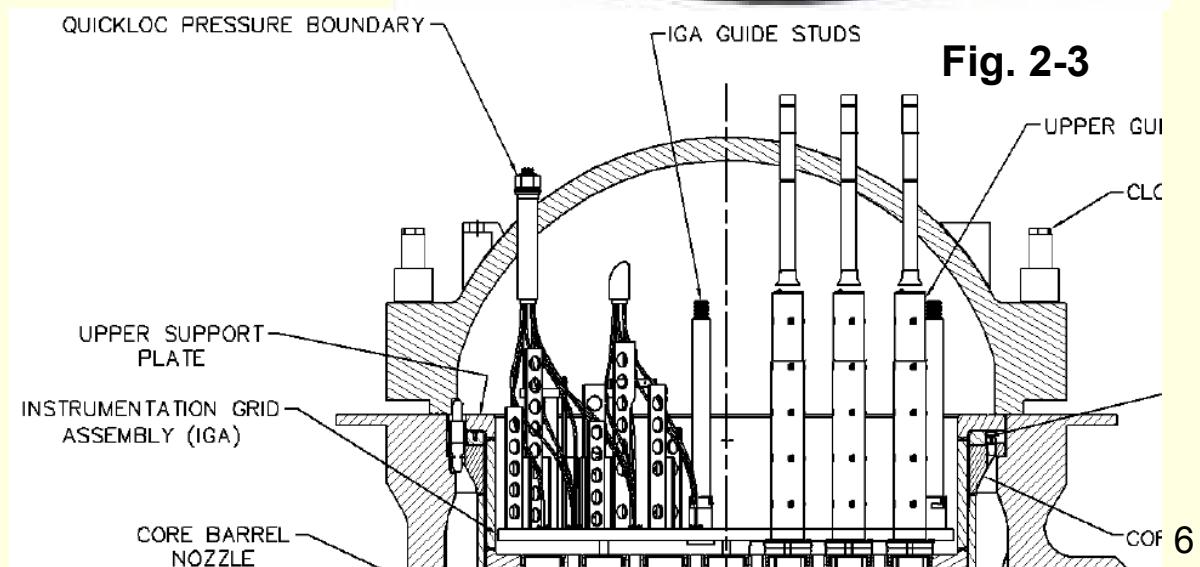
- Directs coolant
  - 4-22" cold leg inlet nozzles
  - Downcomer
  - 2-31" hot leg outlet nozzles
- Nozzles support and locate primary coolant loop piping
- Direct vessel injection safety feature
- Hot and cold leg nozzles are offset for RCP maintenance



# Reactor Vessel Functions (cont.)

- Aligns and Supports
  - CRDM
  - Instrumentation
- Instrumentation tube and CRDM head adapters welded to closure head
  - Alloy 690 material
  - “J-groove” welds

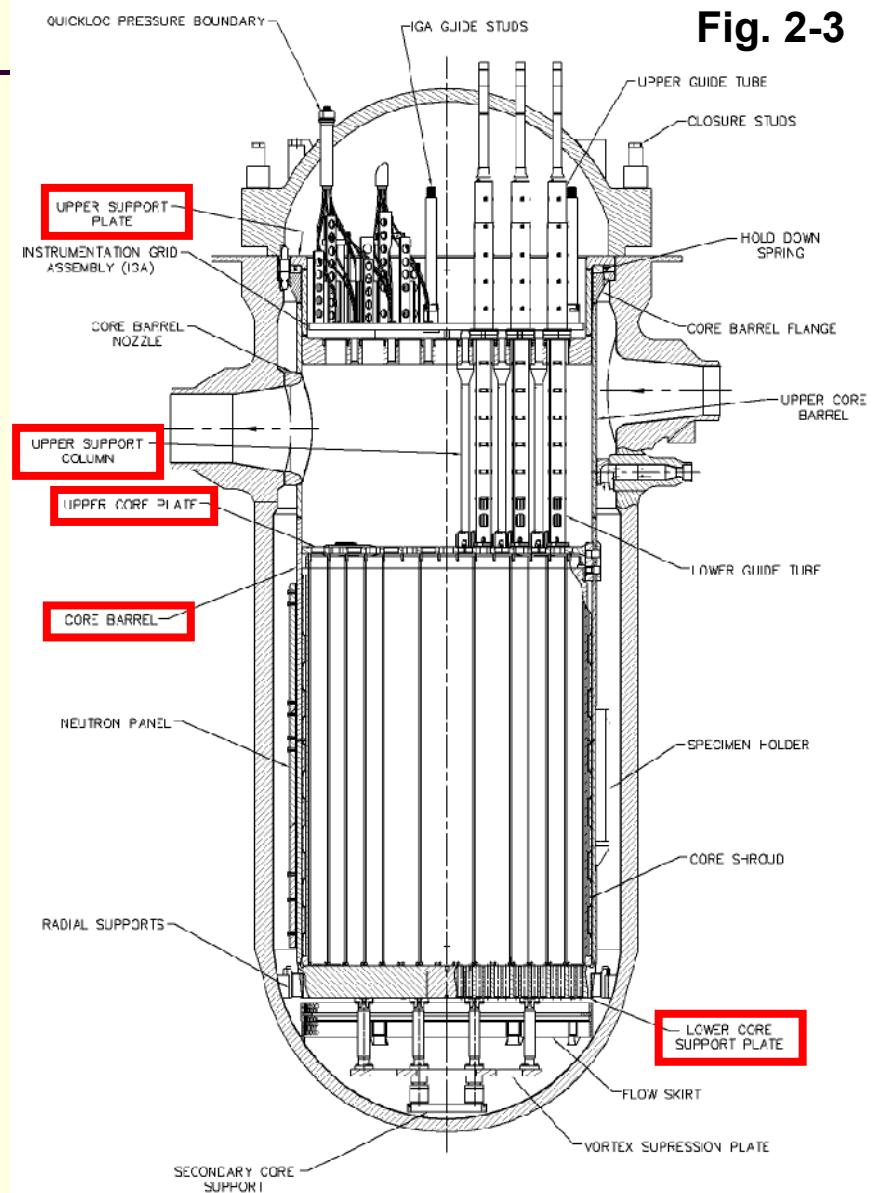
\* There are fewer holes in the head for incore instrument penetrations than shown (details upcoming).



# Reactor Internals General Functions

Fig. 2-3

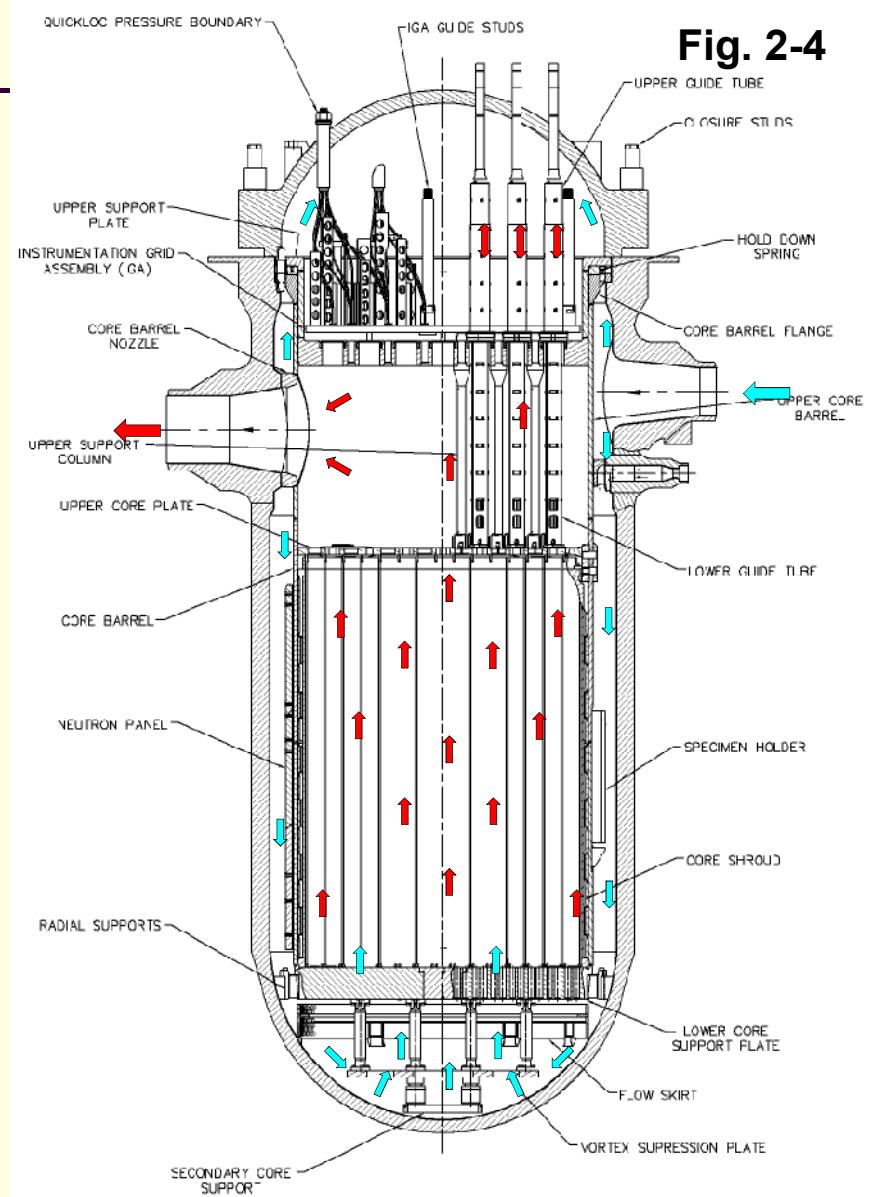
- Provides support and alignment for fuel assemblies
- Accommodates differential thermal expansion
- Key components
  - Core barrel
  - Upper core support plate
  - Upper support columns
  - Upper core plate
  - Lower core support plate



# Reactor Internals General Functions (cont.)

Fig. 2-4

- Directs reactor coolant to fuel assemblies
- Provides cooling flow to the reactor vessel head plenum
- Key components
  - Core barrel
  - Lower core support plate
  - Core shroud



# Reactor Internals General Functions (cont.)

- Provides guidance for the RCCA control rods
- Key components
  - Upper and lower guide tubes
- Provides support and alignment for “top-mounted” incore instrumentation

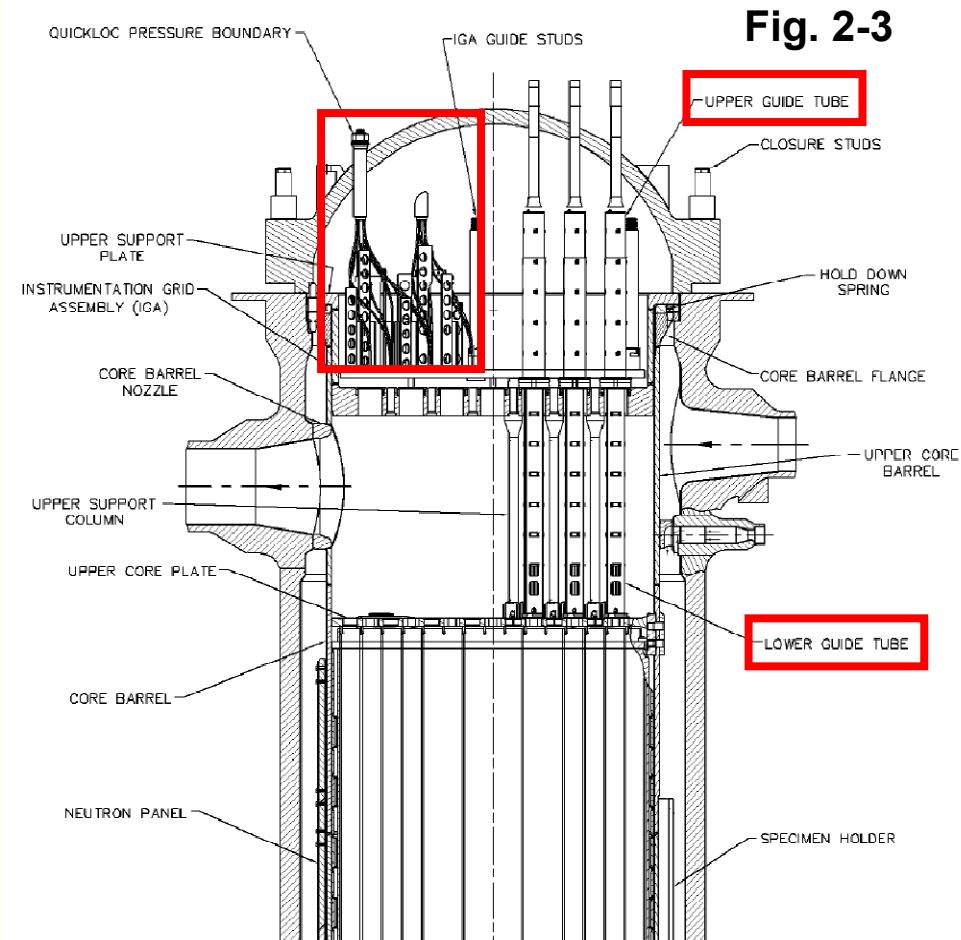
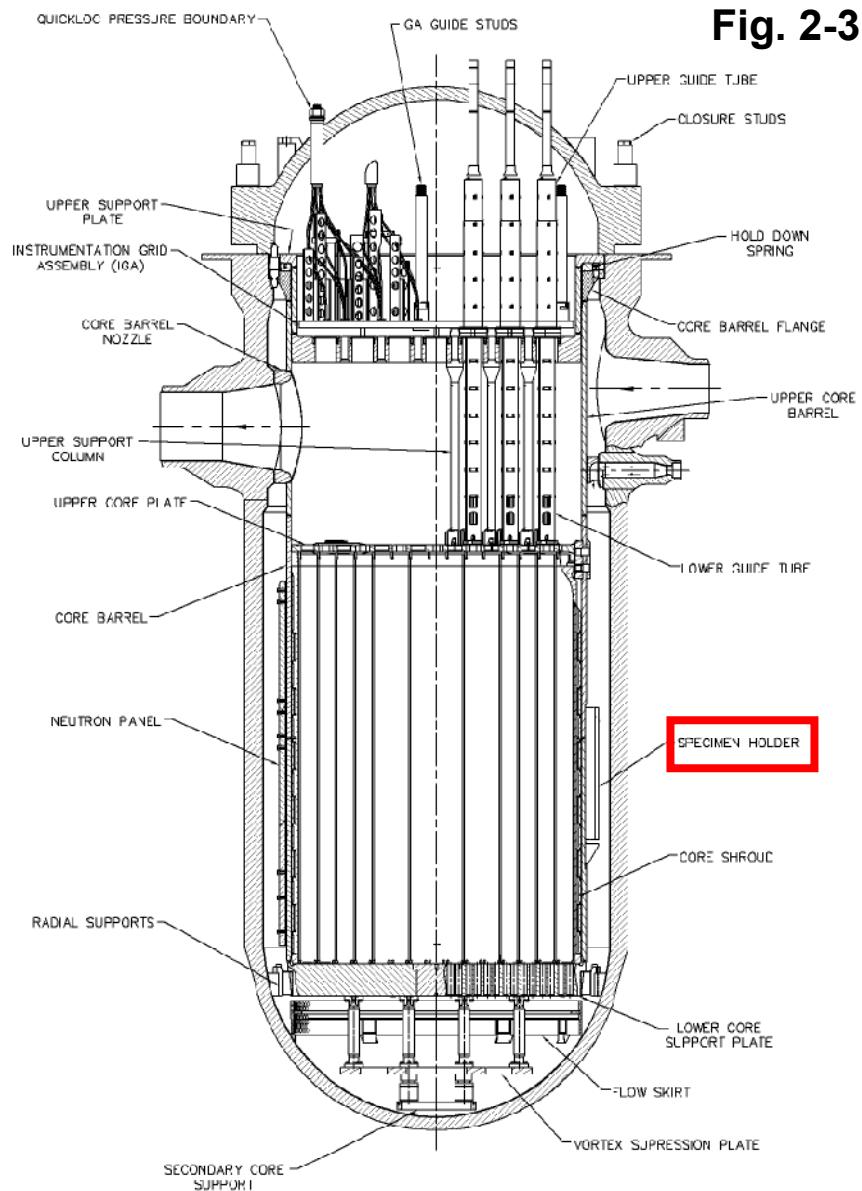


Fig. 2-3

# Reactor Internals General Functions (cont.)

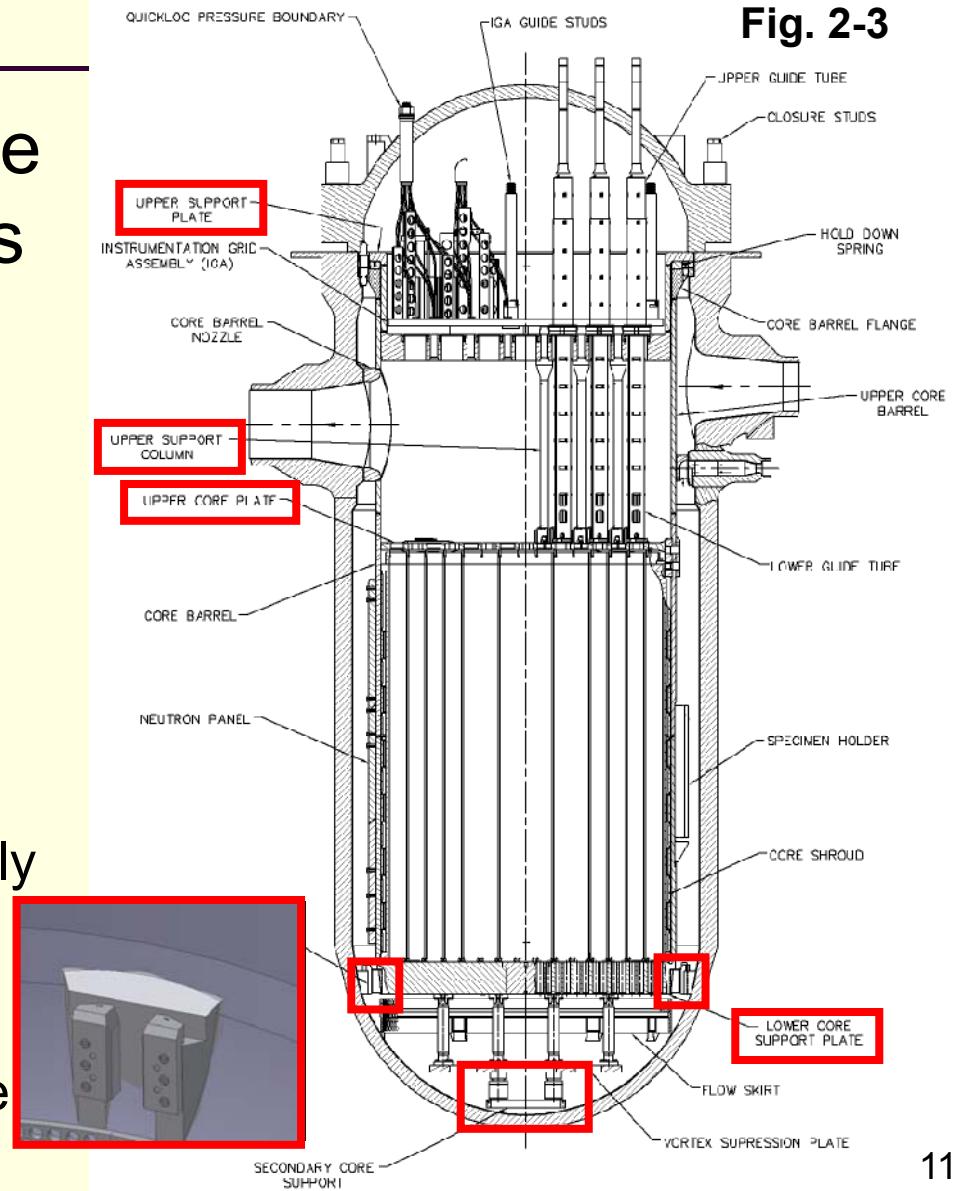
- Supports and orients the RV material surveillance capsules
- Key components
  - Irradiation specimen baskets
  - 3 azimuthal basket locations (135, 225, and 315 degrees)
  - 8 specimen capsules



# Reactor Internals General Functions (cont.)

Fig. 2-3

- Transmit loads from the reactor vessel internals to the RV
- Restricts rotational/translational motion
  - Radial support keys engage clevis inserts in the RV
- Key components
  - Upper core support assembly
  - Radial keys
  - Lower core support plate
  - Secondary support structure



# Integrated Head Package (IHP)

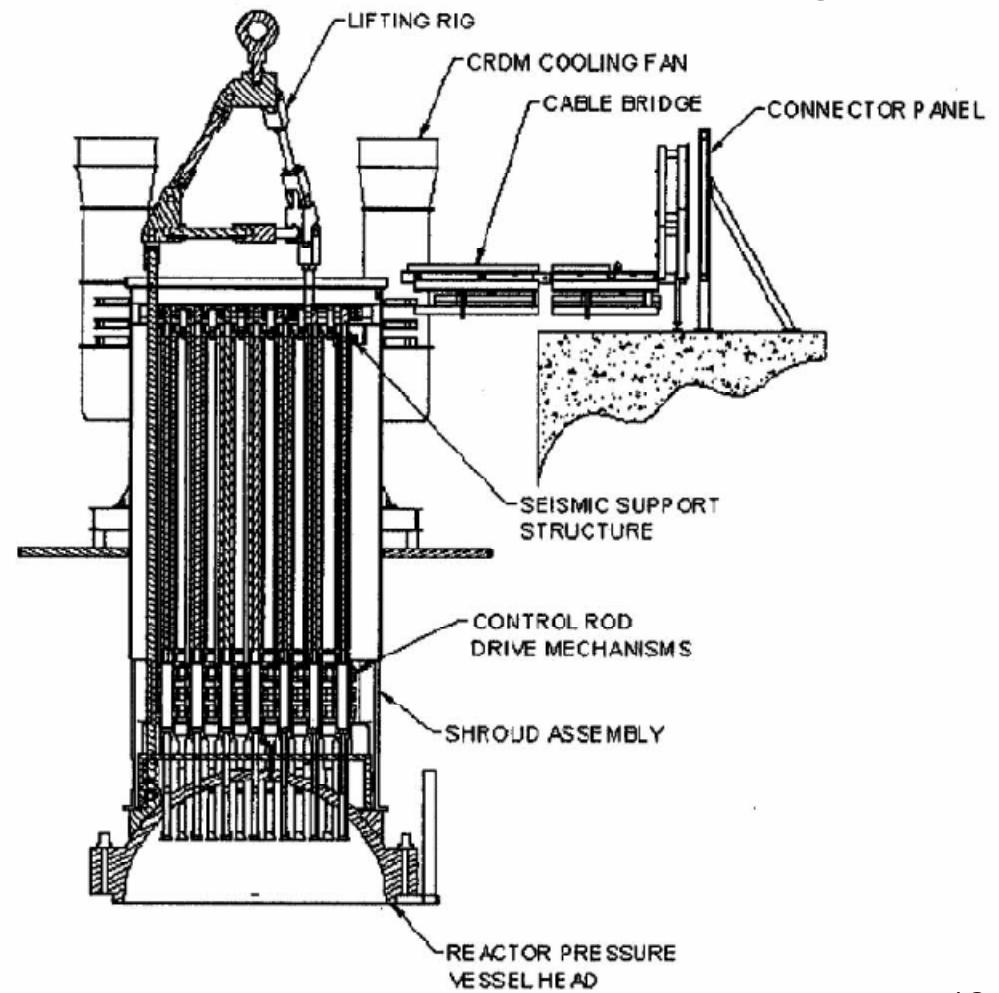
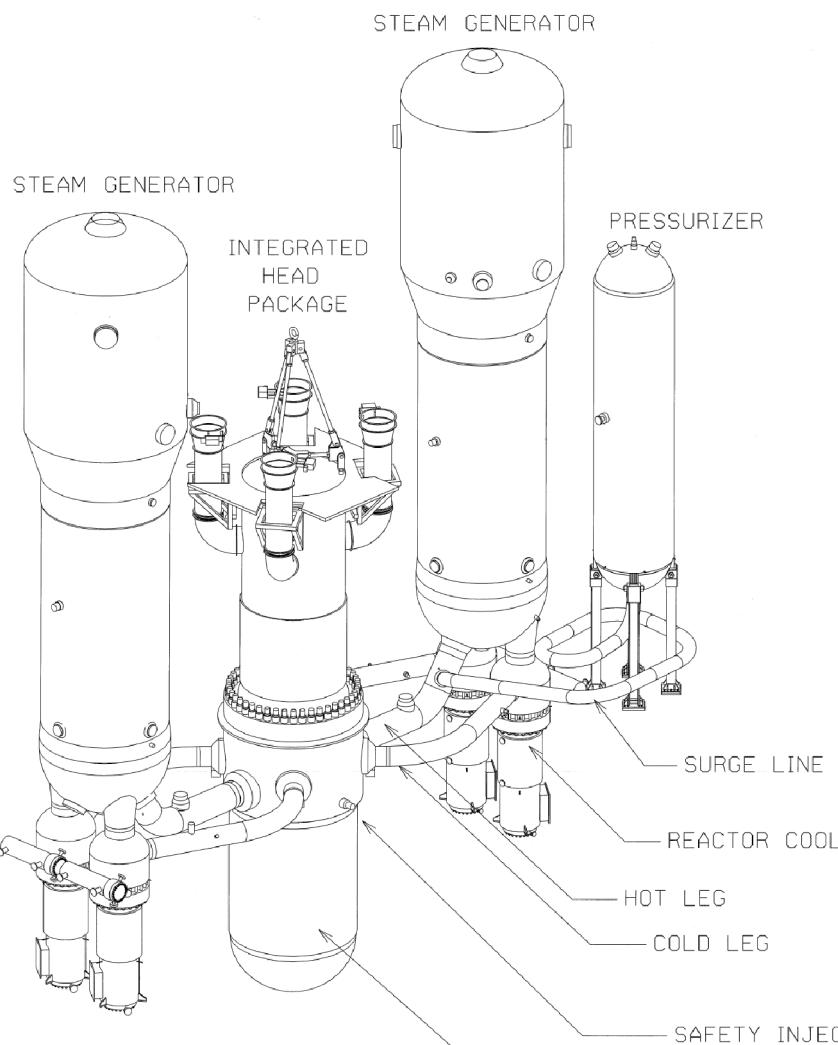


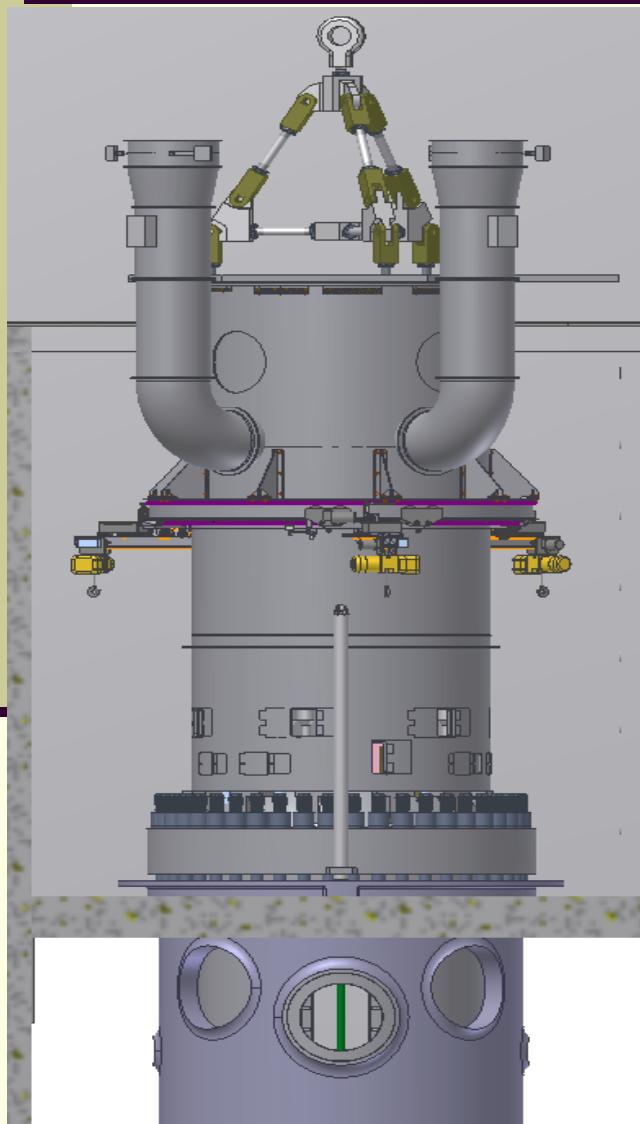
Fig. 2-5

# IHP Basic Functions



- IHP combines several components into one assembly:
  - Lifting rig
  - Seismic restraint for CRDMs
  - Cooling for CRDMS
  - Support for head vent, electrical and I&C cables, including incore instrumentation cables & connectors
  - Support for vessel head stud tensioning
  
- Simplifies refueling the reactor

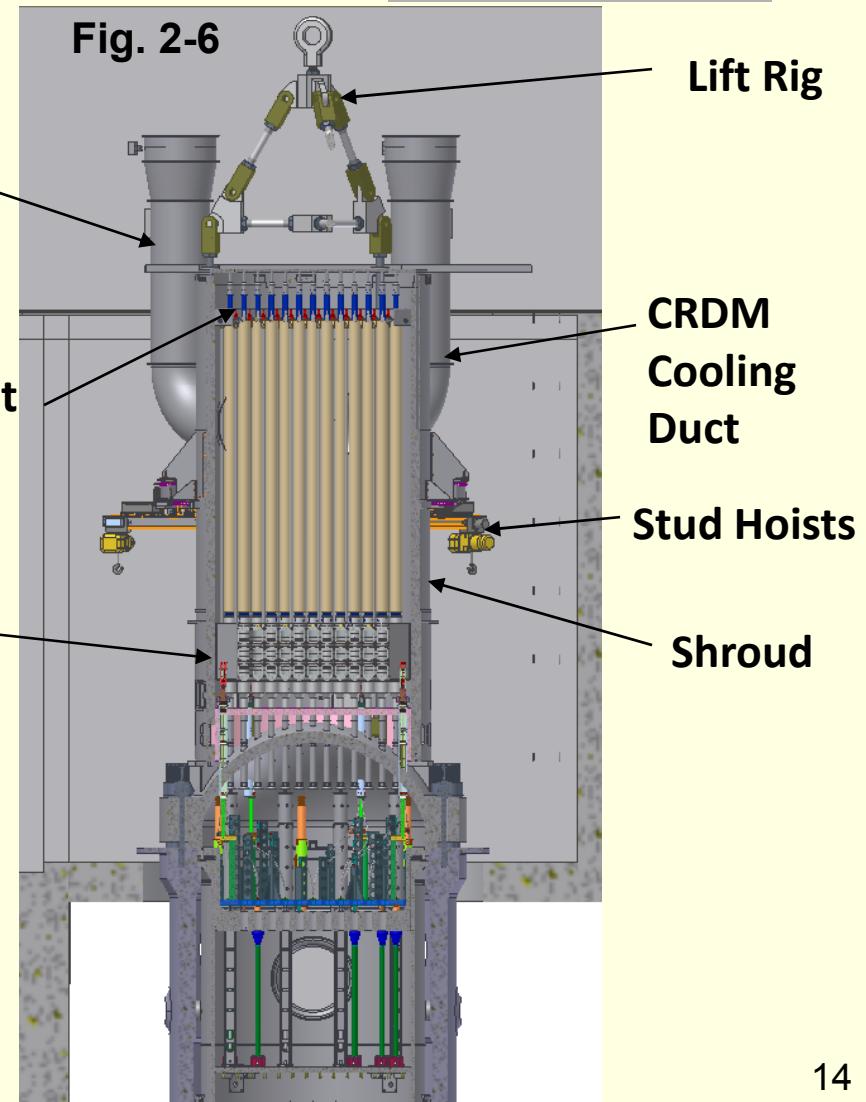
# IHP Components



**CRDM  
Cooling Fans**

**Seismic Restraint  
For CRDMs**

**Quicklocs**



**Lift Rig**

**CRDM  
Cooling  
Duct**

**Stud Hoists**

**Shroud**

# IHP Design Features

- Designed to support top-mounted fixed incore instrumentation (42 detectors)
  - Provides support for incore instrumentation cables & connectors
  - Detectors disconnected at Quickloc penetrations; detectors & guide tubes stay with upper internals during refueling (like later CE designs)
- Features to support 17-day refueling outage
  - Head electrical and I&C cables attached onto two connector panels with quick disconnects
  - Access doors for ICI, CRDM, and bare metal inspection of head

# Incore Instrumentation Support

- With recent design change (DCD rev. 17), incore instrument guide tubes are collected into 8 “stalks” which terminate in Quickloc head penetrations.
- Incore instruments will stay with upper internals during refueling, thus no need for incore guide structures in IHP.

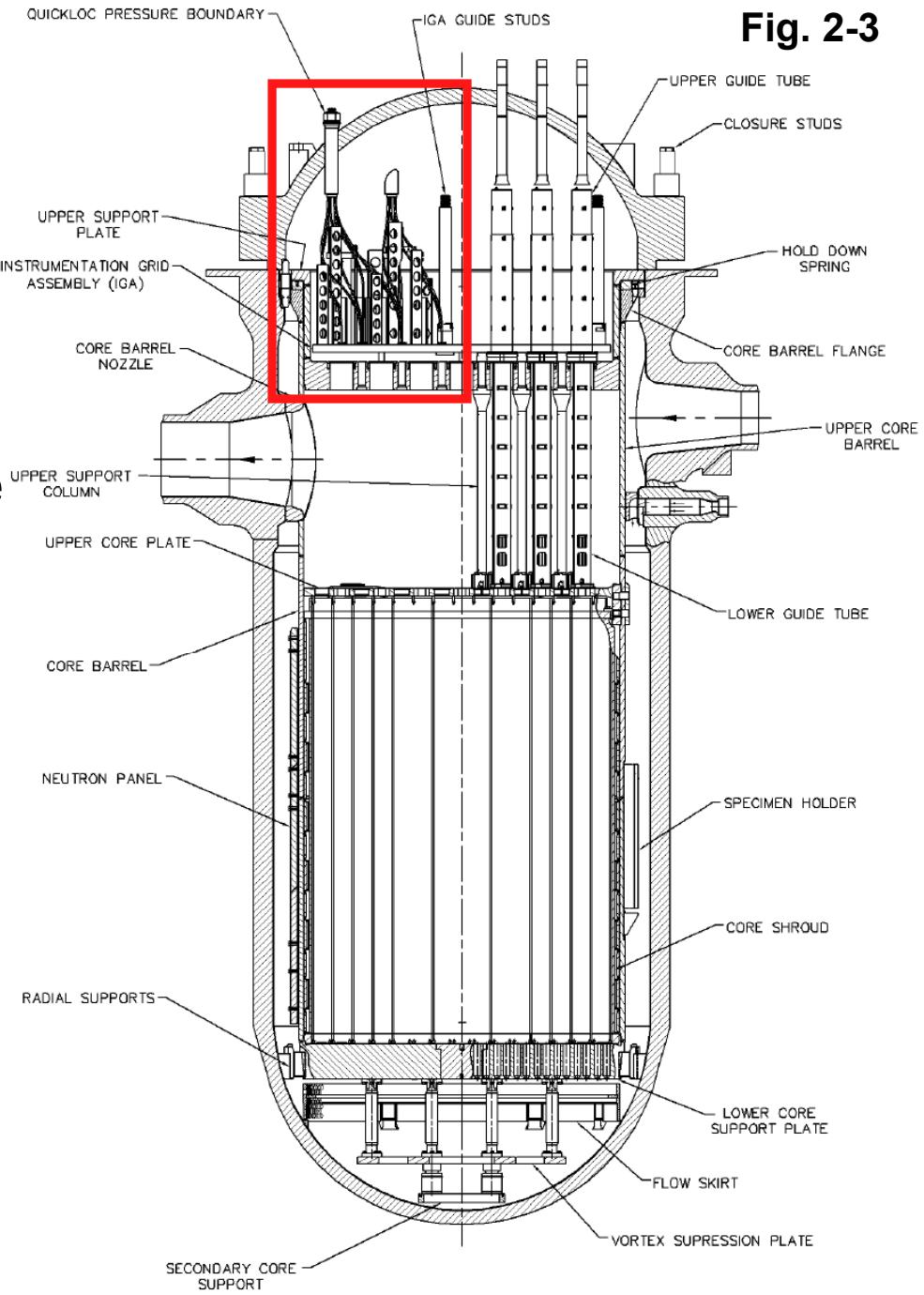


Fig. 2-3

# Revised Integrated Head Package

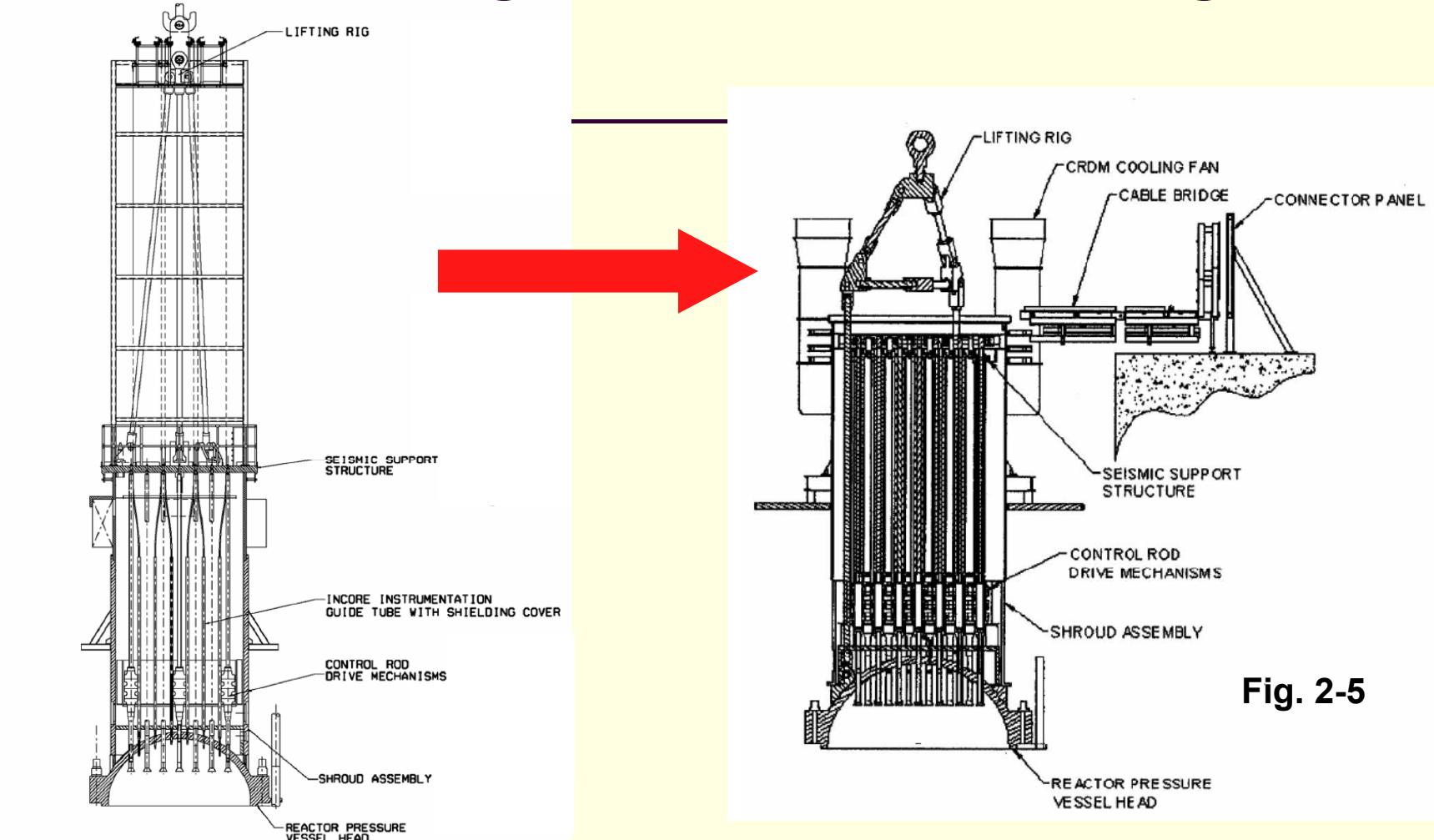


Fig. 2-5

With deletion of incore instrument guide tubes, IHP becomes shorter & lighter. CRDM cooling fans are now mounted directly on the IHP.

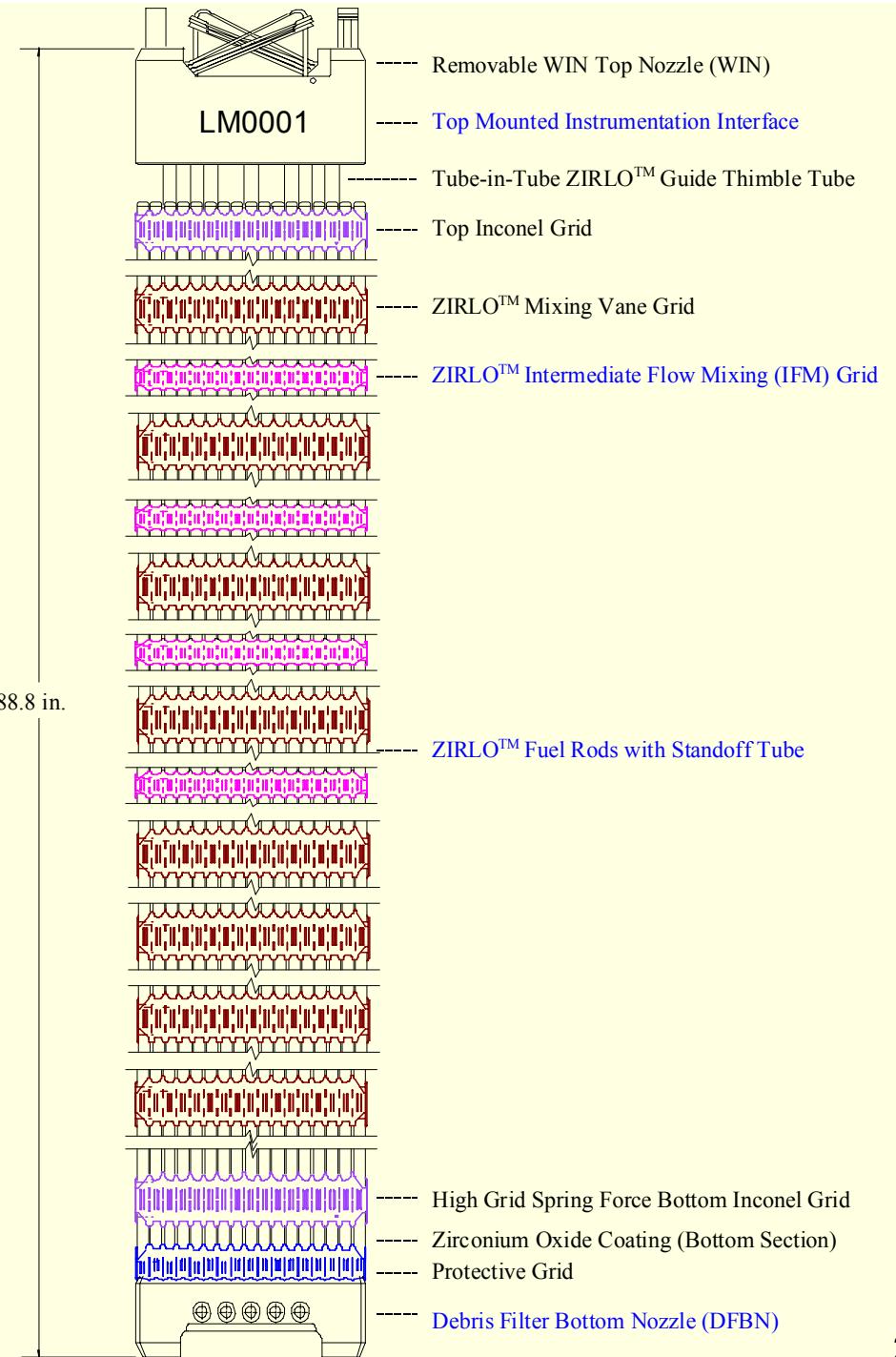
# Core Design Features

- Standard 18-month reloads (510 EFPD) with capability to go to 24 months
- Core power density consistent with current operating plants
- Top-mounted fixed incore instrumentation
- Rod control system using gray rods for load changes
  - Boron changes limited to fuel depletion, startup and shutdown
- **Rapid Power Reduction System**
  - Allows full load rejection capability with only 40% steam dump

# Fuel Assembly

- Based on current 17x17XL fuel in use worldwide

# Fuel Assembly



# Fuel Rod

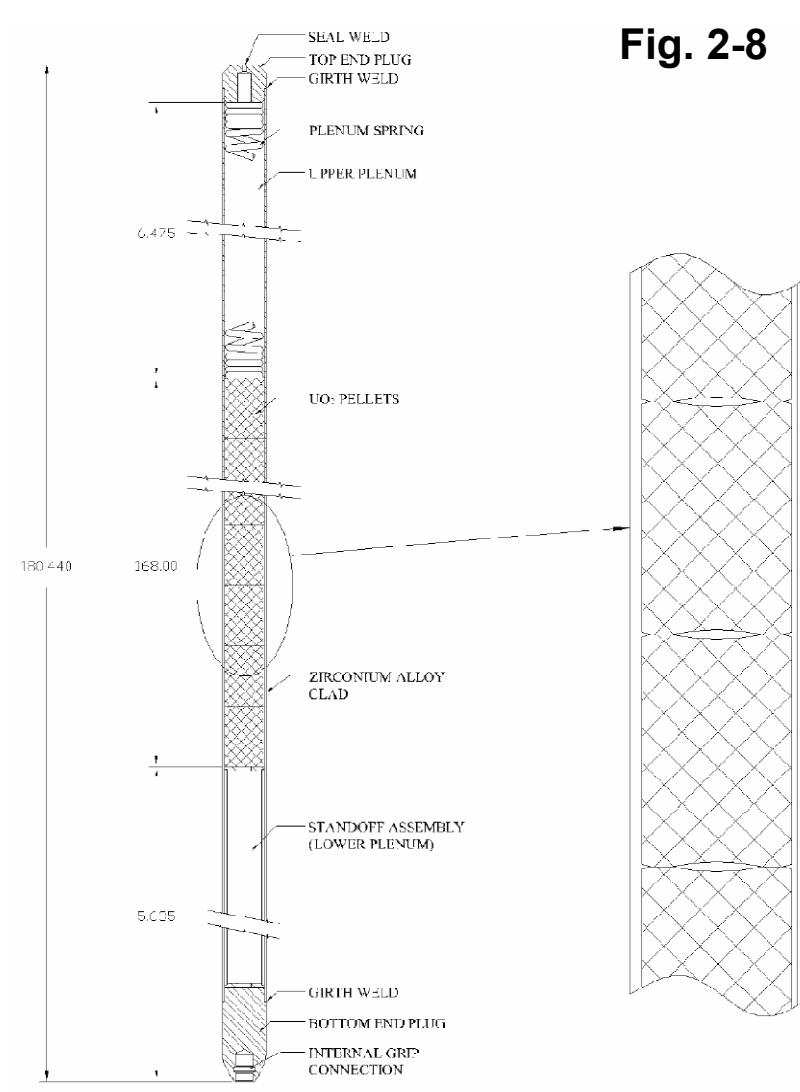


Fig. 2-8

**Integral fuel burnable absorbers**

- boride-coated fuel pellets
- Or
- fuel pellets containing gadolinium oxide mixed with uranium oxide

# Control Rods and Gray Rods

- Control rods very similar to those in current Westinghouse plants
  - 24 rodlets: Silver-indium-cadmium alloy encased in stainless steel tubes
  - 53 rod cluster control assemblies
- Gray rods (DCD): Similar to control rods in construction.
  - 12 of the 24 rodlets are SS
  - 12 rodlets are silver-indium-cadmium
  - 16 gray rod cluster assemblies
- Gray rods (WCAP-16943)\*
  - 24 tungsten rodlets double encapsulated

DIMENSIONS ARE IN INCHES (NOMINAL)  
UNLESS NOTED OTHERWISE

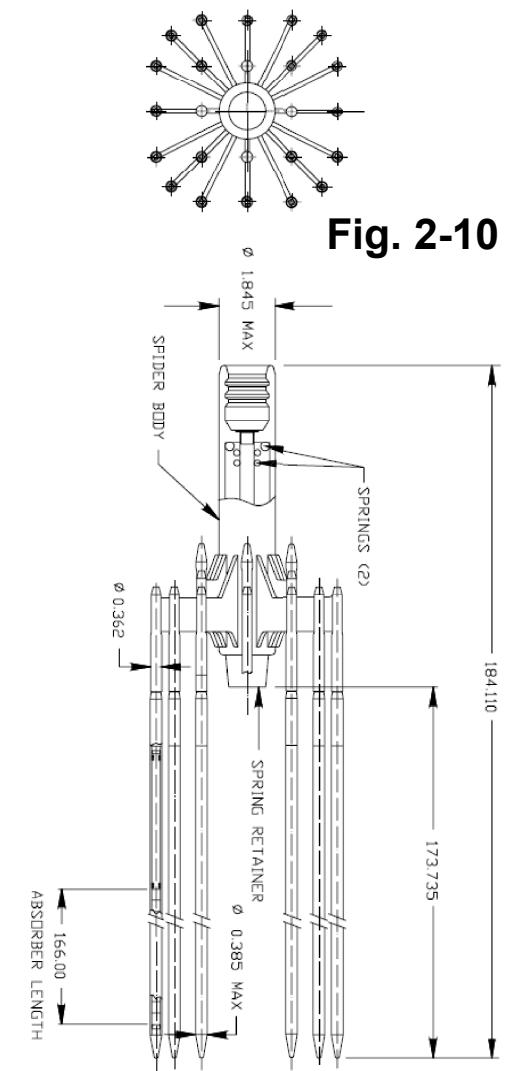


Fig. 2-10

\*Change under NRC review

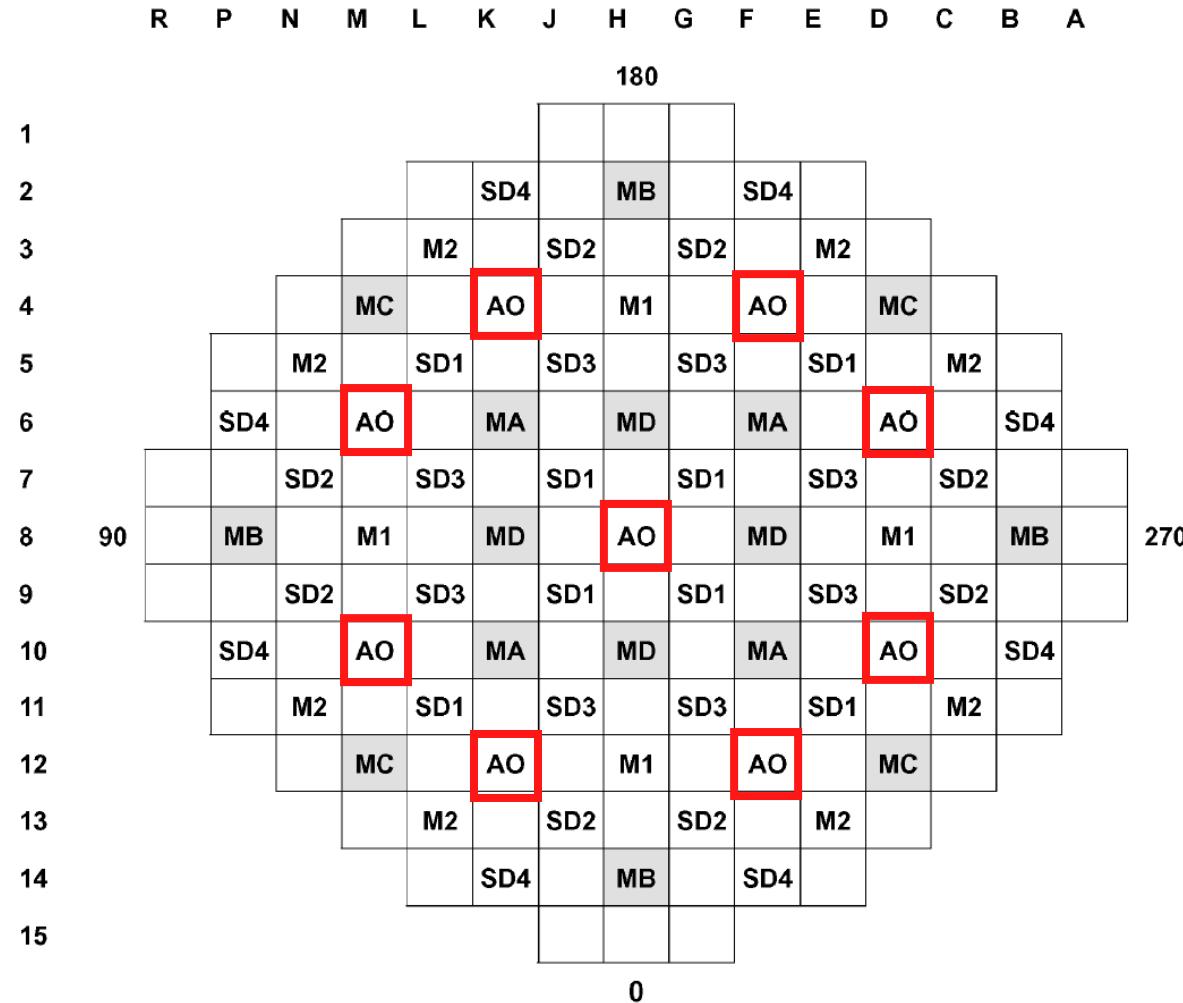
# MSHIM Operation

- The automated mode of control rod operation is referred to as mechanical shim (MSHIM).
- MSHIM operation eliminates the requirement for boron concentration change with power change.
- AP1000 operational boron change requirements are limited to startup, shutdown, and fuel depletion.
- MSHIM control strategy fully automated at power levels  $> \sim 30\%$  (DCD rev. 16).

# MSHIM Control Rod Functions



- MSHIM uses three separate sets of control rods for three unique reactivity control requirements:
  - “SD” Banks for rapid shutdown (Rx Trip)
  - “AO” Bank for axial power distribution control
  - “M” Banks for reactivity control associated with temperature, power level, and transient xenon changes
- The rod control system automatically modulates the AO bank to control axial power distribution simultaneous with MSHIM gray and control rod banks to maintain programmed RCS Tavg.



Bank	Number of Clusters
MA ( MSHIM Gray Bank A )	4
MB ( MSHIM Gray Bank B )	4
MC ( MSHIM Gray Bank C )	4
MD ( MSHIM Gray Bank D )	4
M1 ( MSHIM Black Bank 1)	4
M2 ( MSHIM Black Bank 2)	8
AO ( A.O. Control Bank )	9
SD1 ( Shutdown Bank 1 )	8
SD2 ( Shutdown Bank 2 )	8
SD3 ( Shutdown Bank 3 )	8
SD4 ( Shutdown Bank 4 )	8
TOTAL	69

Gray Rod Position  
 AO Rod Position

**Fig. 2-14**

# Rapid Power Reduction System



- Reactor power control system designed to respond to a full load rejection without initiating a reactor trip.
- Load rejections requiring > 50% reduction of rated thermal power initiates the rapid power reduction system.
- System utilizes preselected control rod groups and/or banks which are intentionally tripped to rapidly reduce reactor power.

# Questions?



## Which one of the following is true concerning the Gray Rod Assemblies?

---

- A. 24 Silver-indium-cadmium rodlets per assembly.
- B. 53 total Grey Rod assemblies in the core.
- C. 12 of the 24 Grey Rod assembly rodlets are stainless steel.
- D. Grey Rod assemblies are 6 feet in length.

**Which one of the following is NOT a feature of the AP1000 core and reactor vessel design?**

---

- A. Four inlet nozzles, one for each RCP discharge pipe.**
- B. Two direct vessel injection nozzles.**
- C. Four outlet nozzles, one for each SG.**
- D. 14-ft fuel assemblies.**